Non-SUSY Exotic Searches at the Tevatron

Qiuguang Liu (Purdue Univ.)

on behalf of the CDF and DØ collaborations

Outline

- Tevatron, CDF and DØ
- Standard Model and it's Extensions
- Exotics Searches at Tevatron (see L. Bellantoni's talk for the SUSY searches)
- Conclusion

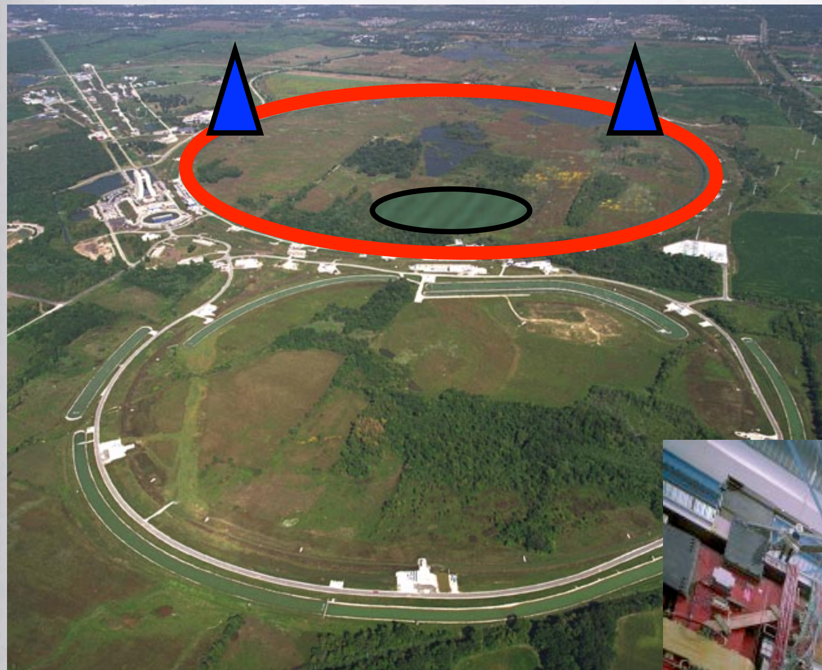
SUSY 2011
at the "high rise"

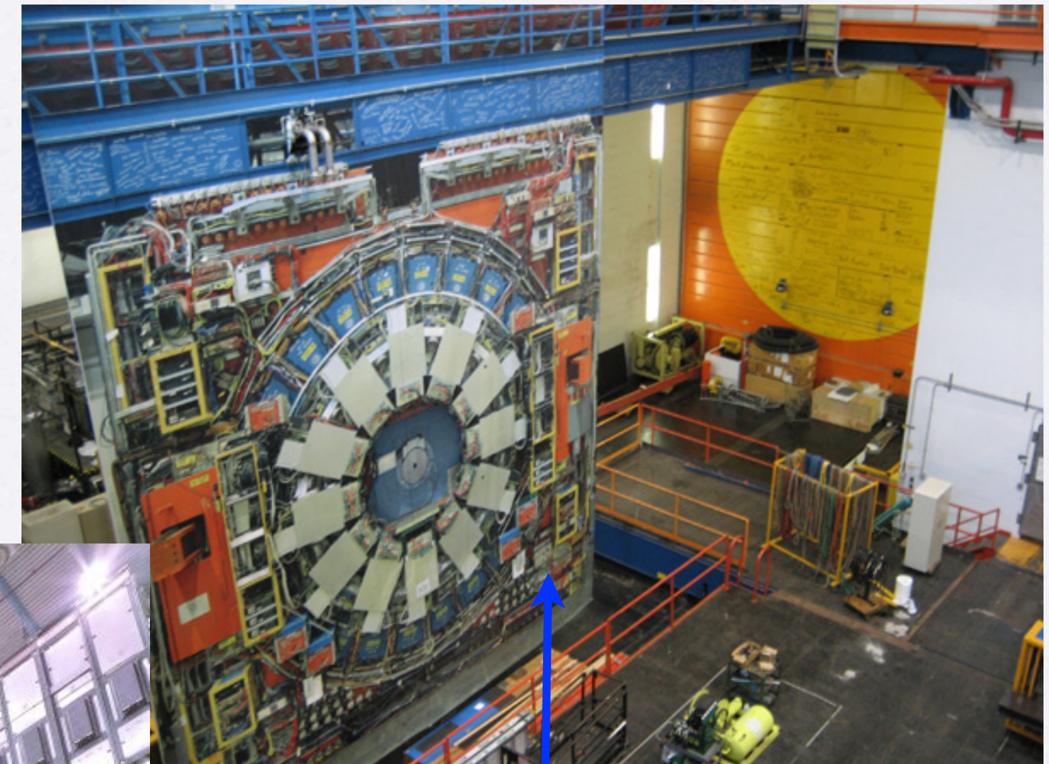
Accelerator	Highest Energy
Cockcroft Walton	750 KeV
Linac	400 MeV
Booster	8 GeV
Main Injector	150 GeV
Tevatron ~ 4 miles	980 GeV

Proton → ← Anti-proton

~ 2 TeV

Two General-purpose Detectors





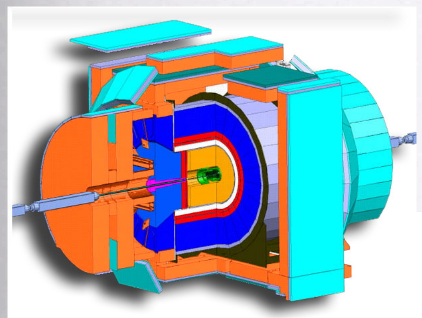
CDF

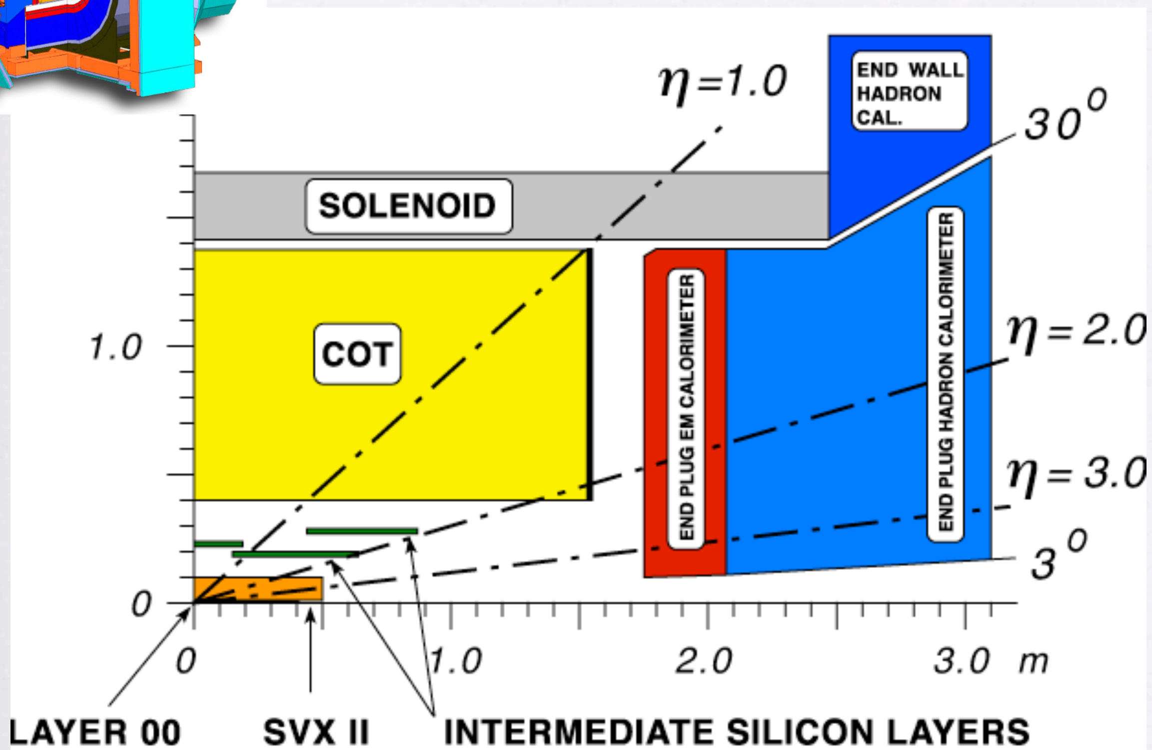
60 institutes, 513 members

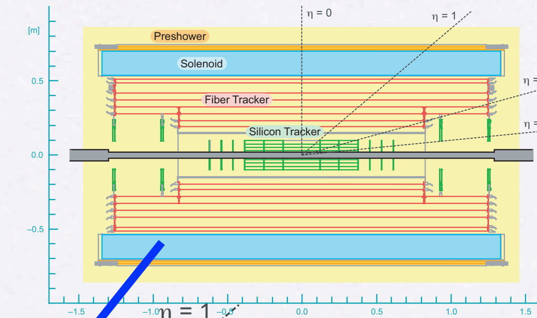
D∅

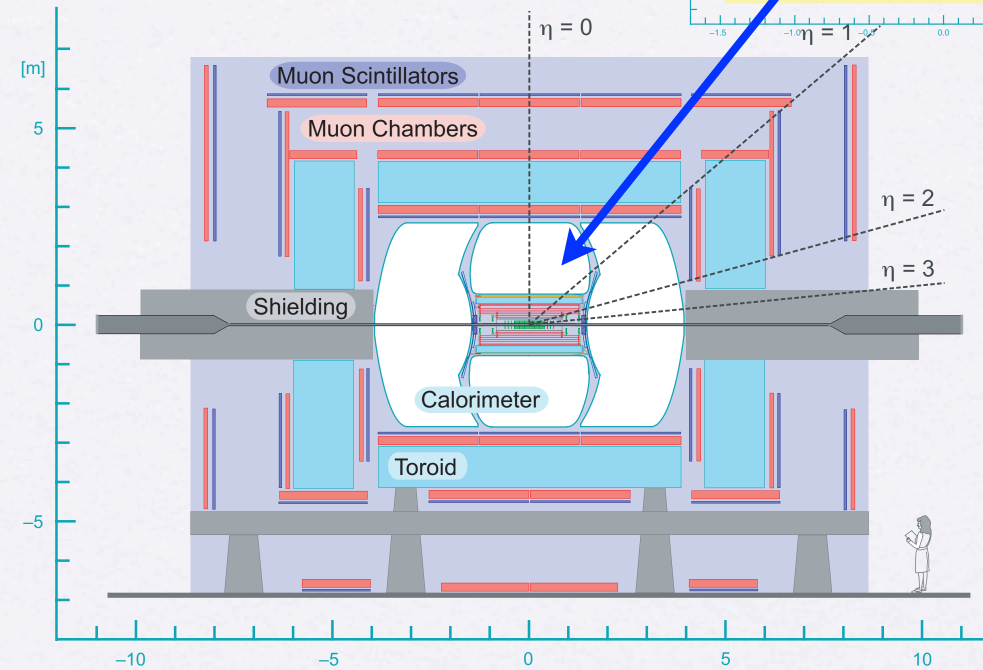
72 institutes, 456 members

CDF and DØ



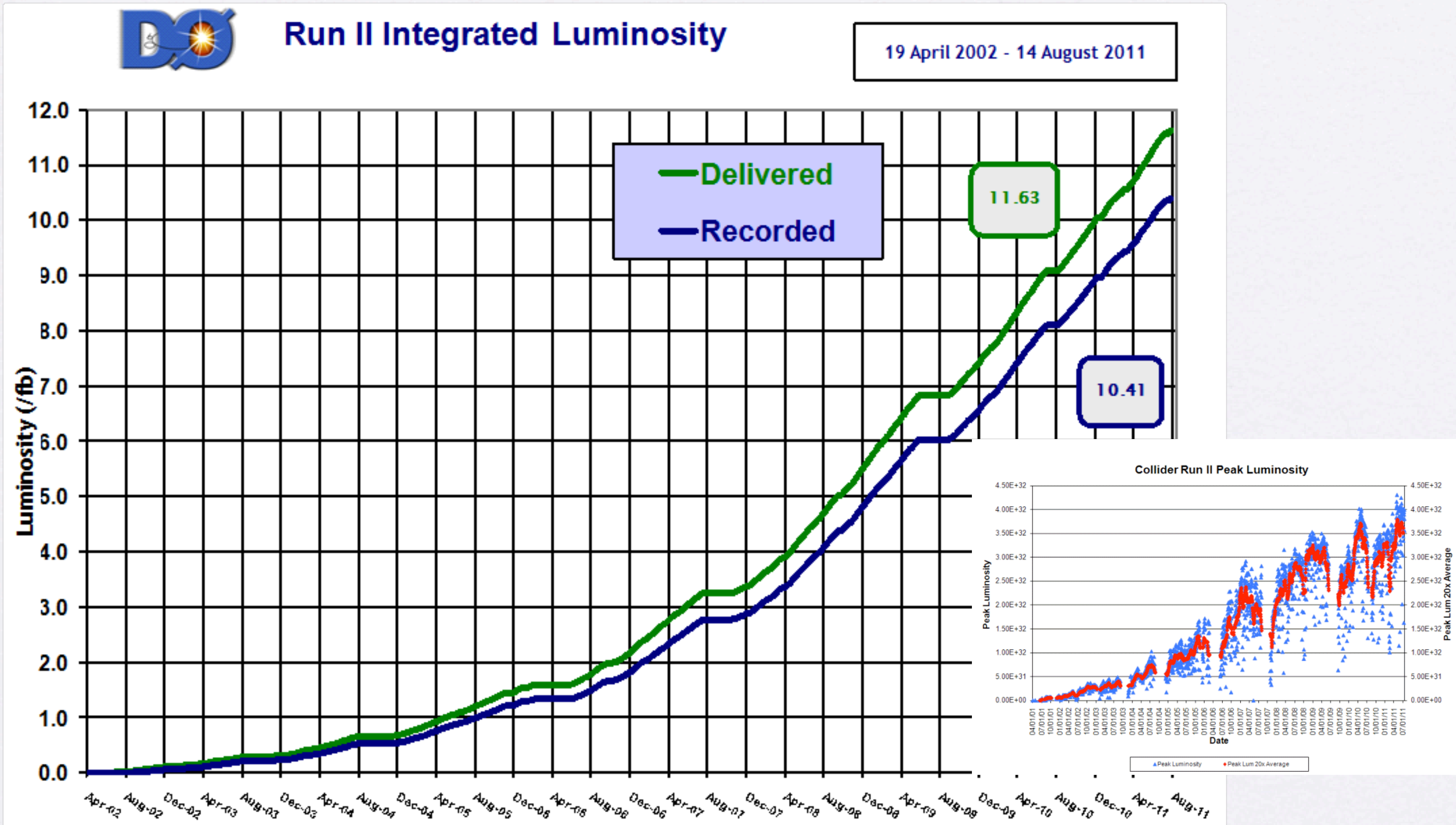






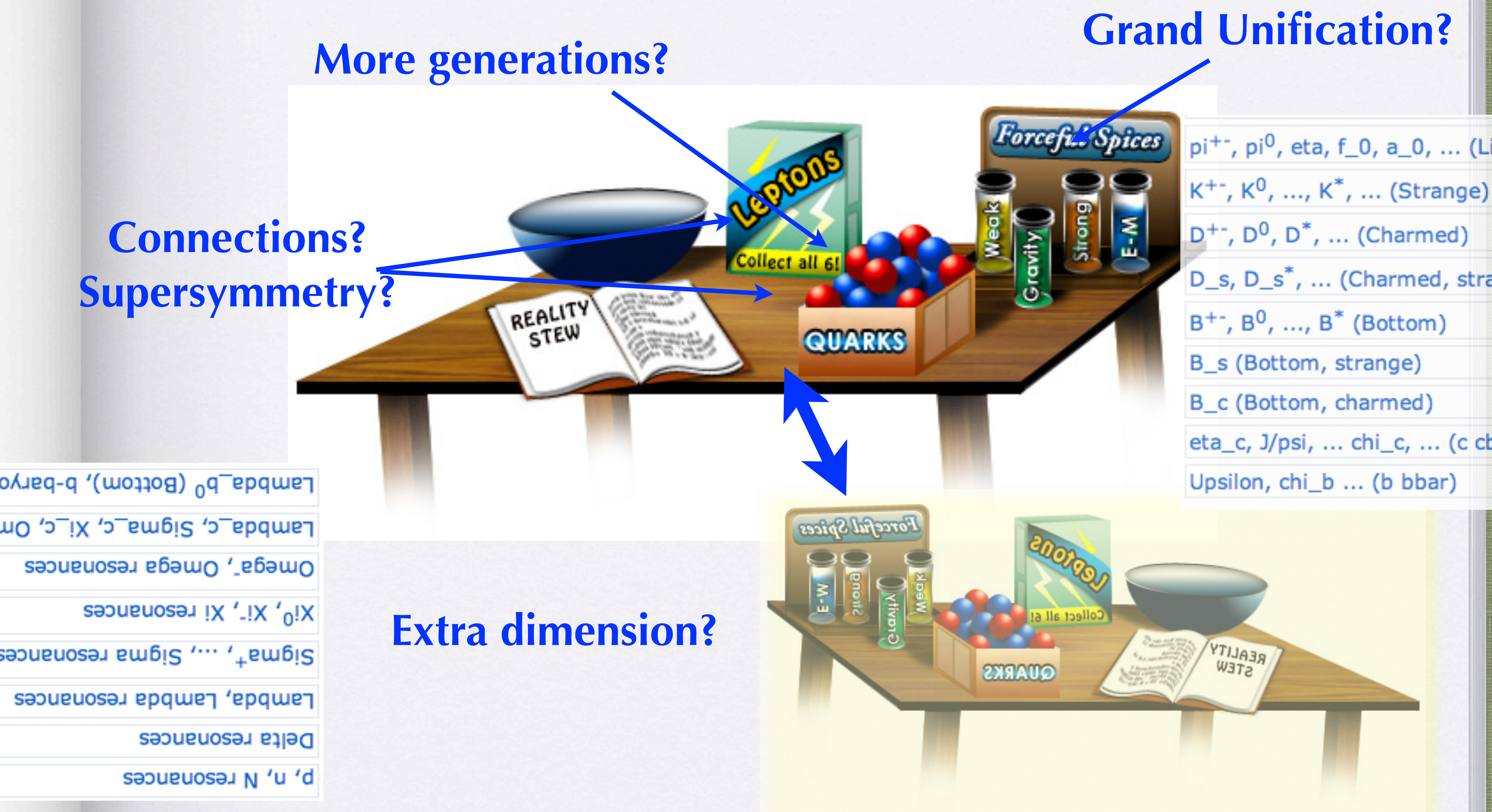
- **Tracking system**: the silicon detectors for vertex precision, the wire/fiber chamber to measure the charged particle momentum.
- **Calorimeters**: measure the energy of electrons and photons, and sample the energy of hadrons.
- **Muon detector**: improve the muon ID.
- Sophisticated systems behind the curtain: Electronics, Trigger Systems, DAQ, Offline Simulation and Reconstruction, and many others.

Collider Performance



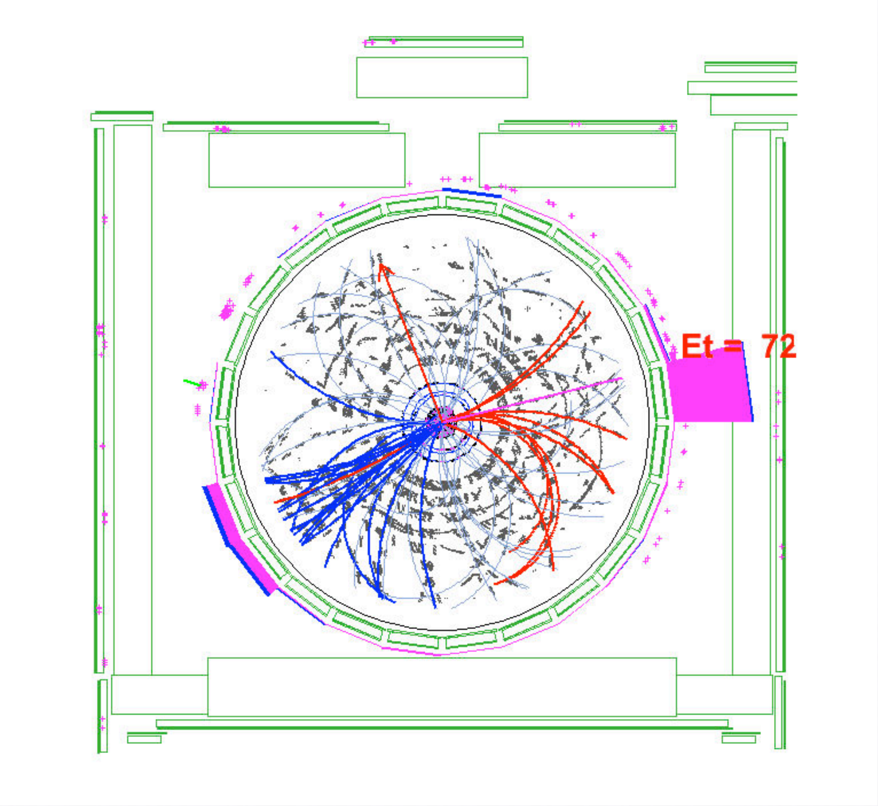
The results showing in this talk are using data about 5~6 fb^{-1}

Extension of the Standard Model



Tevatron Exotics Searches

- Many extensions of Standard Model are proposed.
- New particles are predicted.
- A measurable new particle show itself as elementary particles after decay: e, μ, τ, ϒ, jets (pion, kaon, n, p ...), and neutrino (missing transverse energy).
- If a model doesn't predict anything measurable, we're sorry ...



Non-SUSY Exotics

- Leptoquark
- RS Graviton G
- SSM W′
- 4th gen. neutrino
- T′, dark matter
- new resonance

Also see the SUSY talk given by L. Bellantoni

Background: Standard Model Productions

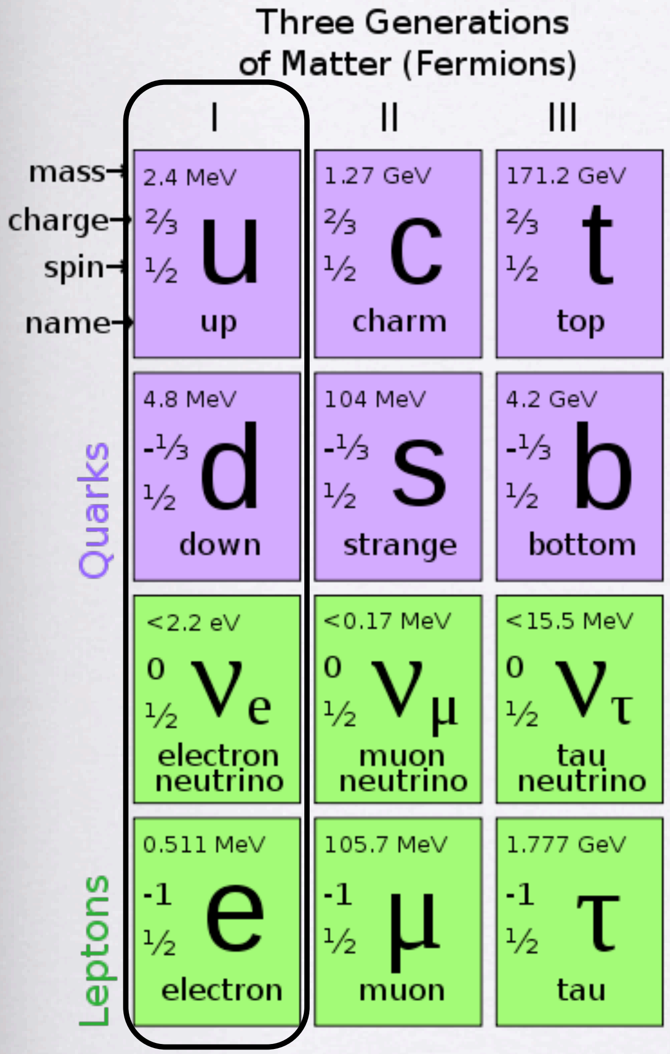
- WW/WZ/ZZ: Pythia (CDF & DØ)
- Single top: MadEvent+Pythia (CDF), COMPHEP(DØ)
- Top pair: Pythia (CDF), Alpgen+Pythia (DØ)
- W/Z + jets: Alpgen+Pythia(CDF & DØ)
- QCD multijet: data-driven

The cross-section is always using the one up to the highest available order

Signal: exotic particles.

- mostly Pythia.

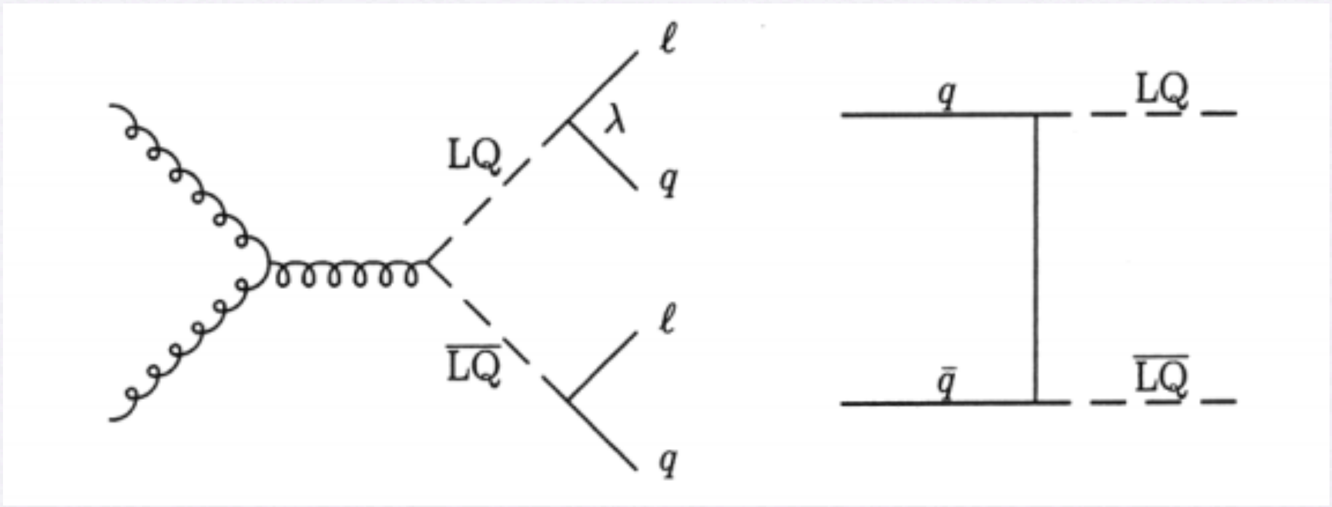
Leptoquarks



Leptoquarks (LQ) are predicted to fundamentally couple the leptons and quarks, in each generation.

$$q + \bar{q} \rightarrow LQ + \overline{LQ}$$

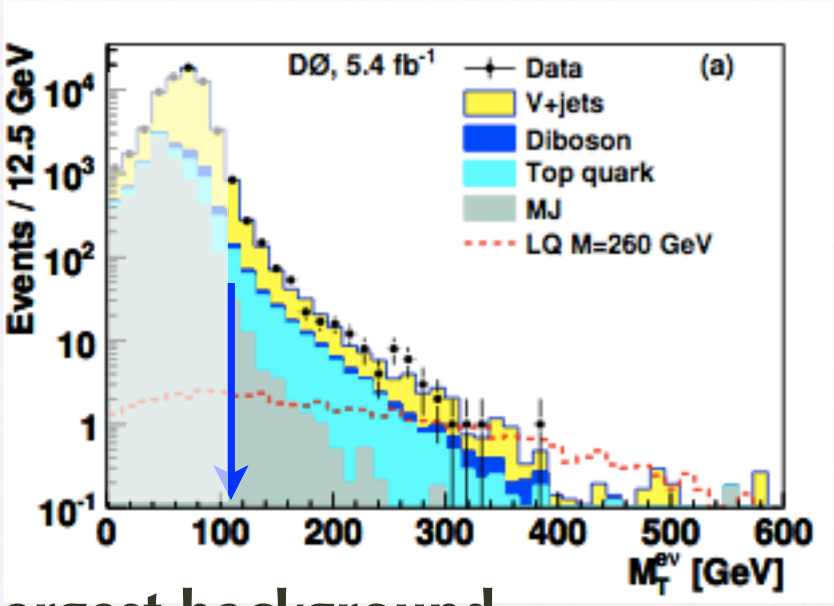
$$g + g \rightarrow LQ + \overline{LQ}$$

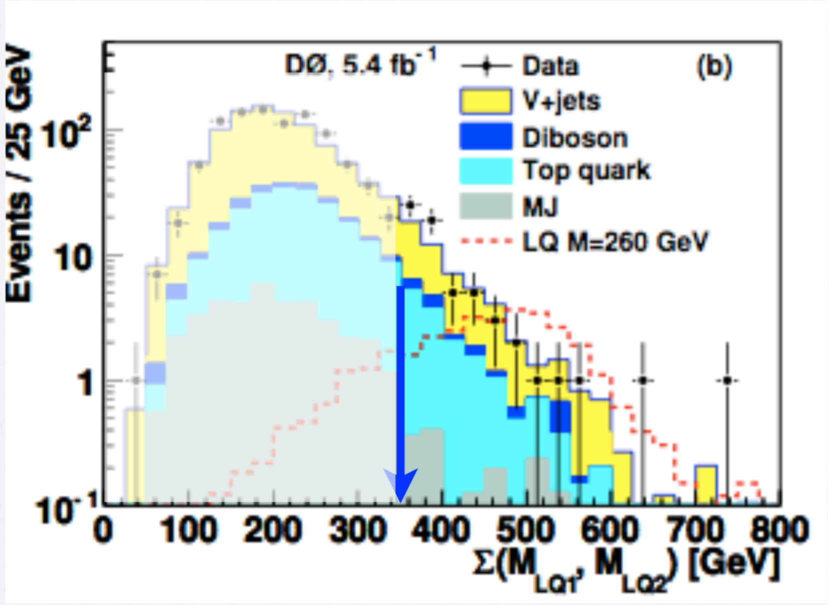


5.4 fb^{-1}

Search for the 1st generation scalar leptoquarks

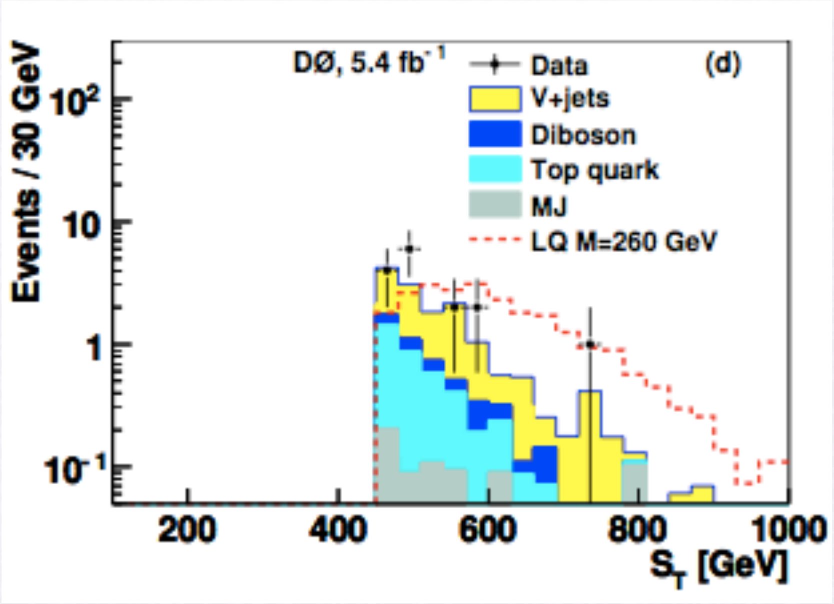
$$LQ\overline{LQ} \to eq\nu_e q'$$





W+jets is the largest background.

$$W \to e\nu,\ \ m_T^{e\nu} \sim [70, 85]\ GeV$$



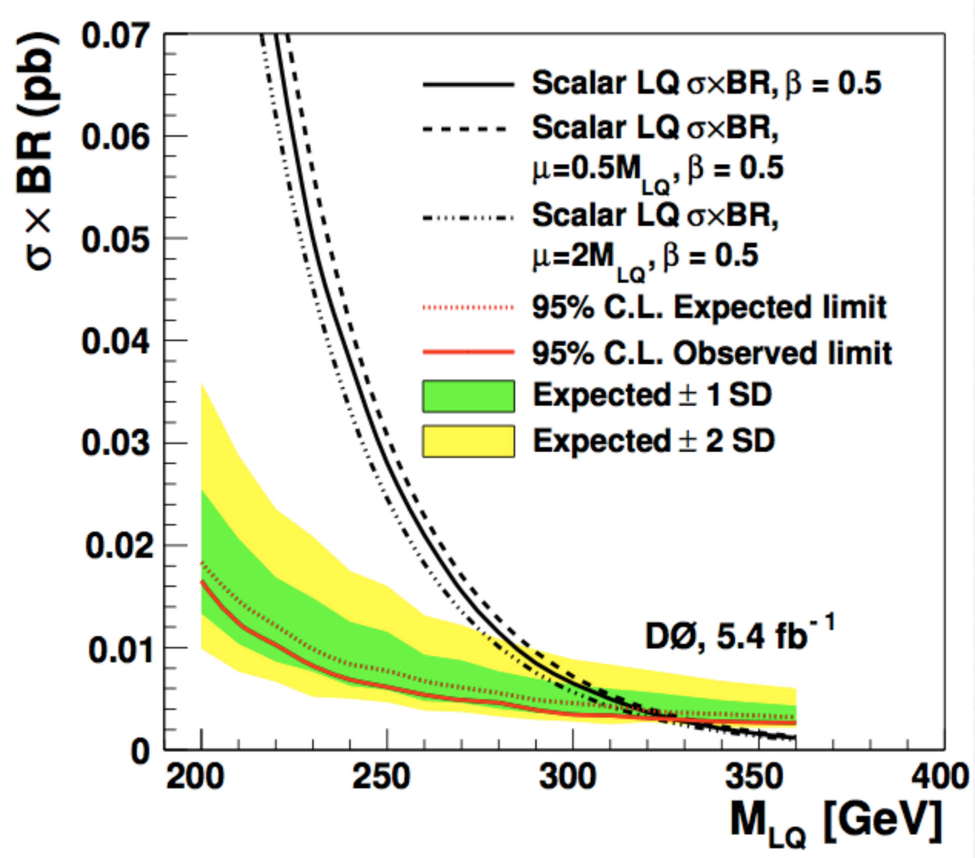
$$S_T = \sum E_{T_{jet}} + E_{T_l} + \not{E}_T$$

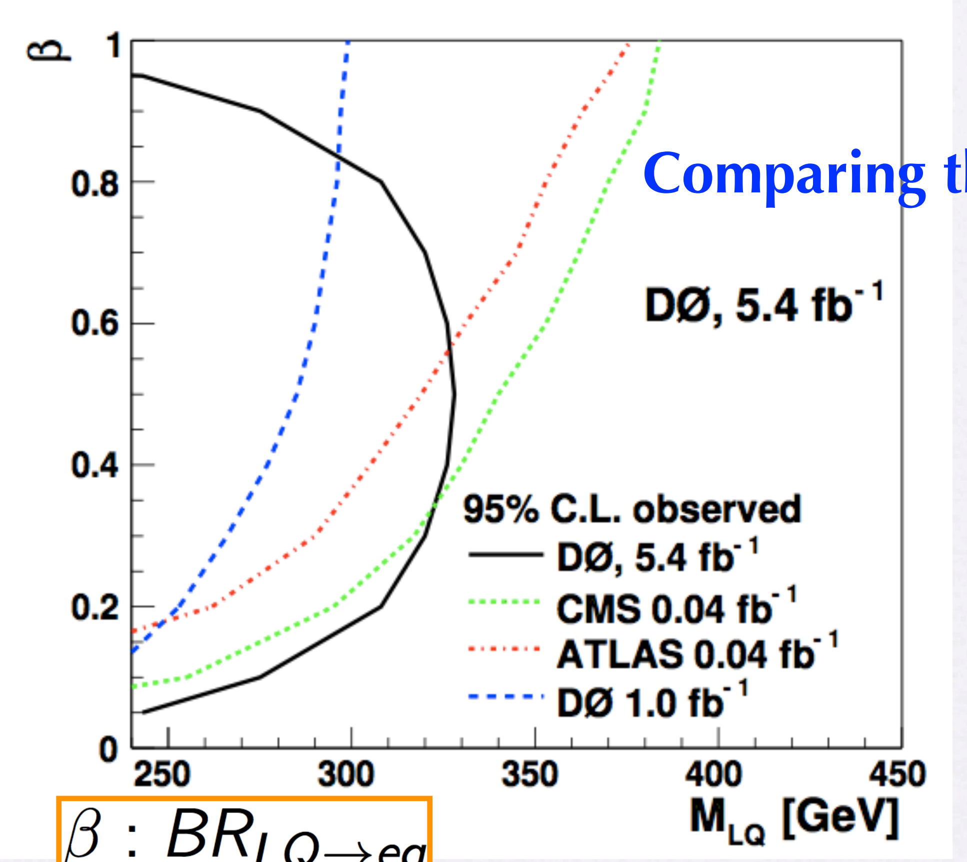
arXiv:1107.1849 [hep-ex]

5.4 fb^{-1}

Search for the 1st generation scalar leptoquarks

$$LQ\overline{LQ} \rightarrow eq\nu_e q'$$





$\beta : BR_{LQ \rightarrow eq}$

Scanning over samples with m_{LQ} 200~360 GeV.
A lower limit of LQ mass is set at 326 GeV (β=0.5).

arXiv:1107.1849 [hep-ex]

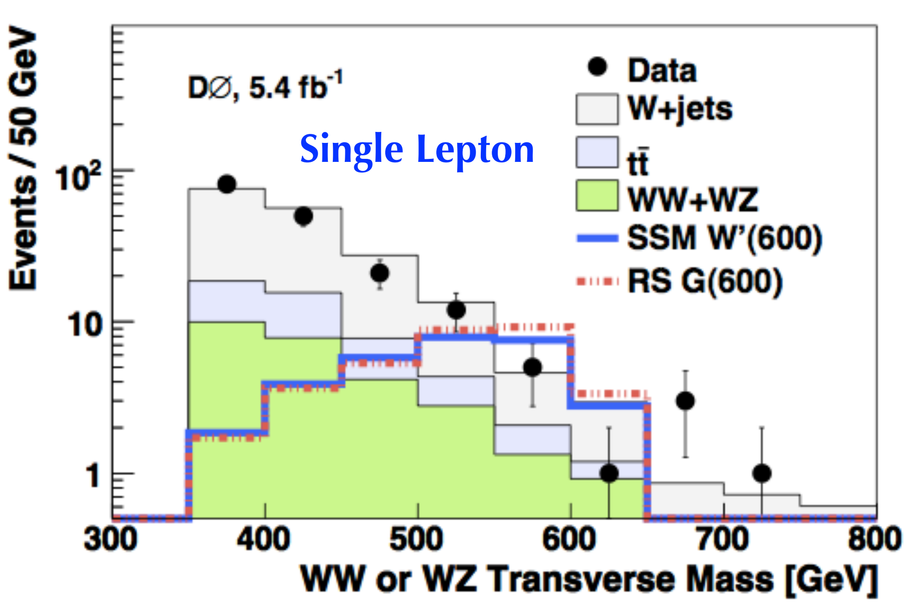
WW or WZ resonance

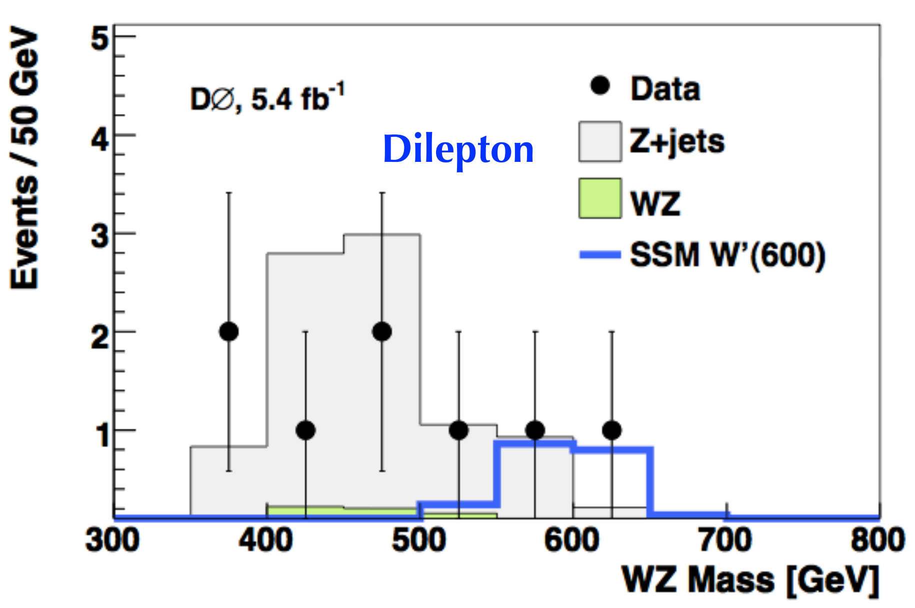
5.4 fb^{-1}

Sequential standard model W′
Randall-Sundrum model graviton G

$$p\bar{p} \to W' \to WZ\ (l\nu jj,\ jjll,\ l\nu ll)$$
$$p\bar{p} \to G \to W^+W^-\ (l\nu jj)$$

Two new searches with ≥1 jet and 1- or 2-lepton (5.4 fb^{-1})
Combined with 3-lepton search (4.1 fb^{-1})





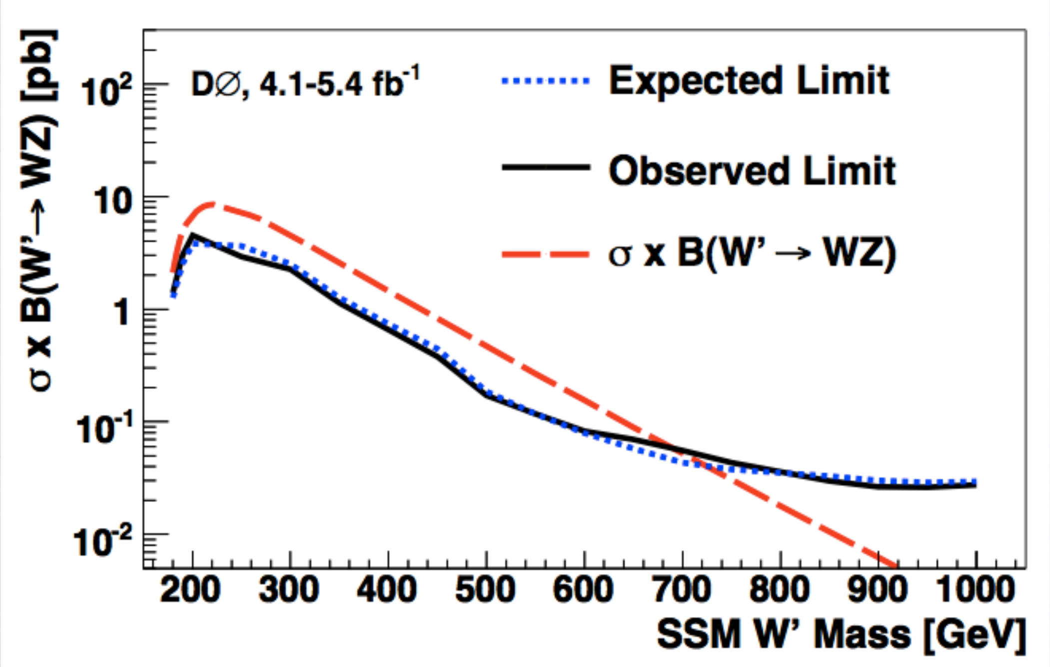
Process	Single lepton sample	Dilepton sample
Z+jets	3.6 ± 0.2	7.9 ± 0.8
W+jets	124.5 ± 20.3	< 0.01
Top	22.9 ± 2.5	< 0.01
Multijet	4.6 ± 0.3	< 0.01
Diboson	27.6 ± 1.4	0.8 ± 0.1
Background sum	183.2 ± 24.5	8.7 ± 0.8
Data	174	8

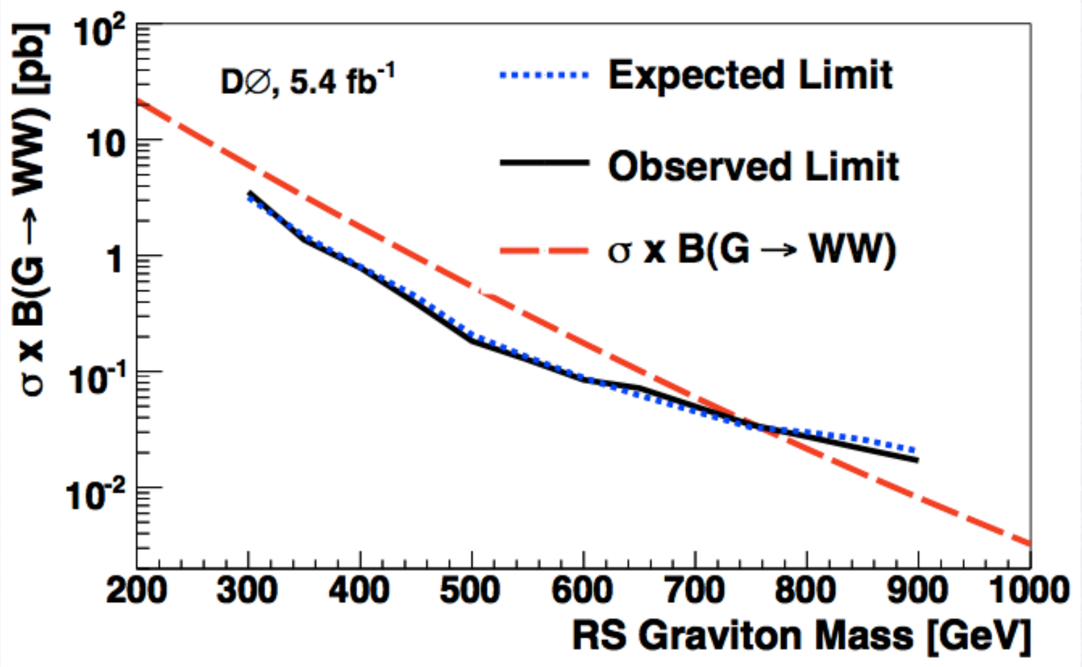
Phys. Rev. Lett. 107, 011801 (2011)

WW or WZ resonance

Sequential standard model W′
Randall-Sundrum model graviton G

$$p\bar{p} \to W' \to WZ\ (l\nu jj,\ jjll,\ l\nu ll)$$
$$p\bar{p} \to G \to W^+W^-\ (l\nu jj)$$



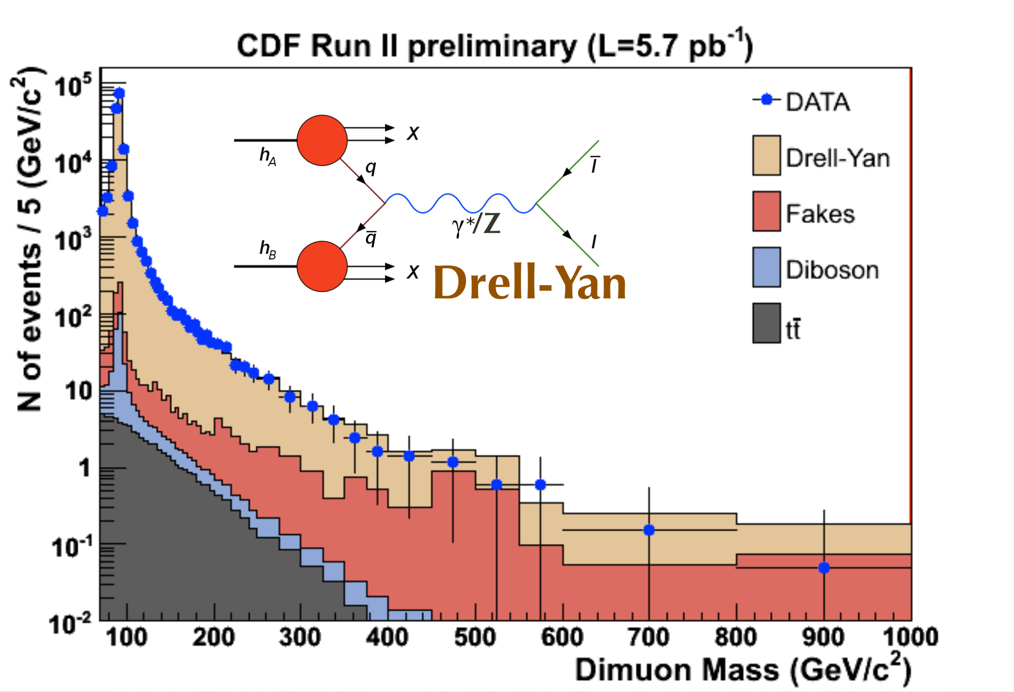


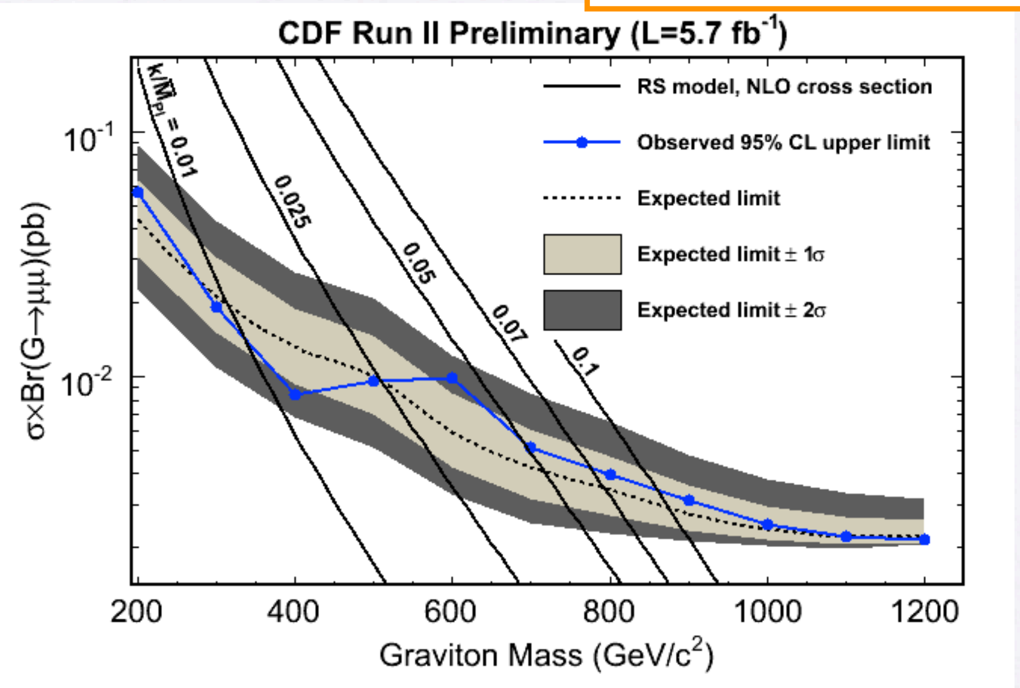
Exclude W′ in the mass range [180, 690] GeV
Exclude RS graviton in [300, 754] GeV ($k/\overline{M}_{pl} = 0.1$)

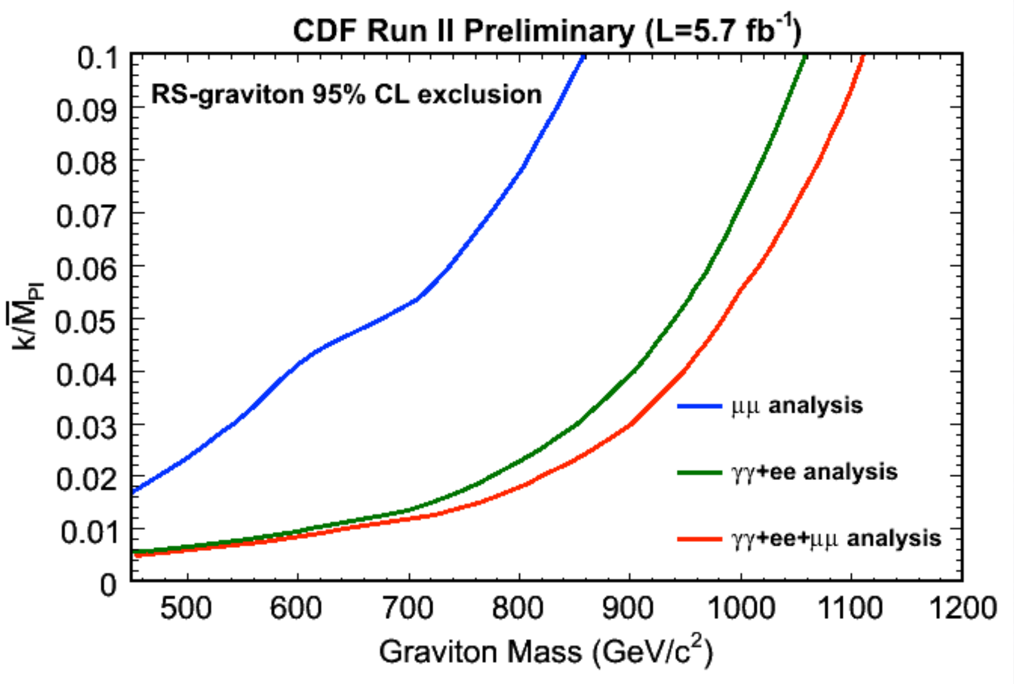
Phys. Rev. Lett. 107, 011801 (2011)

Search for Randall-Sundrum Graviton in μμ channel

$G \to \mu\mu,\ ee,\ \gamma\gamma$







Combined with the searches in ee (5.7 fb^{-1}) and YY (5.4 fb^{-1}) channels

The RS graviton mass limit for the coupling $k/\overline{M}_{pl} = 0.1$ is 1111 GeV.

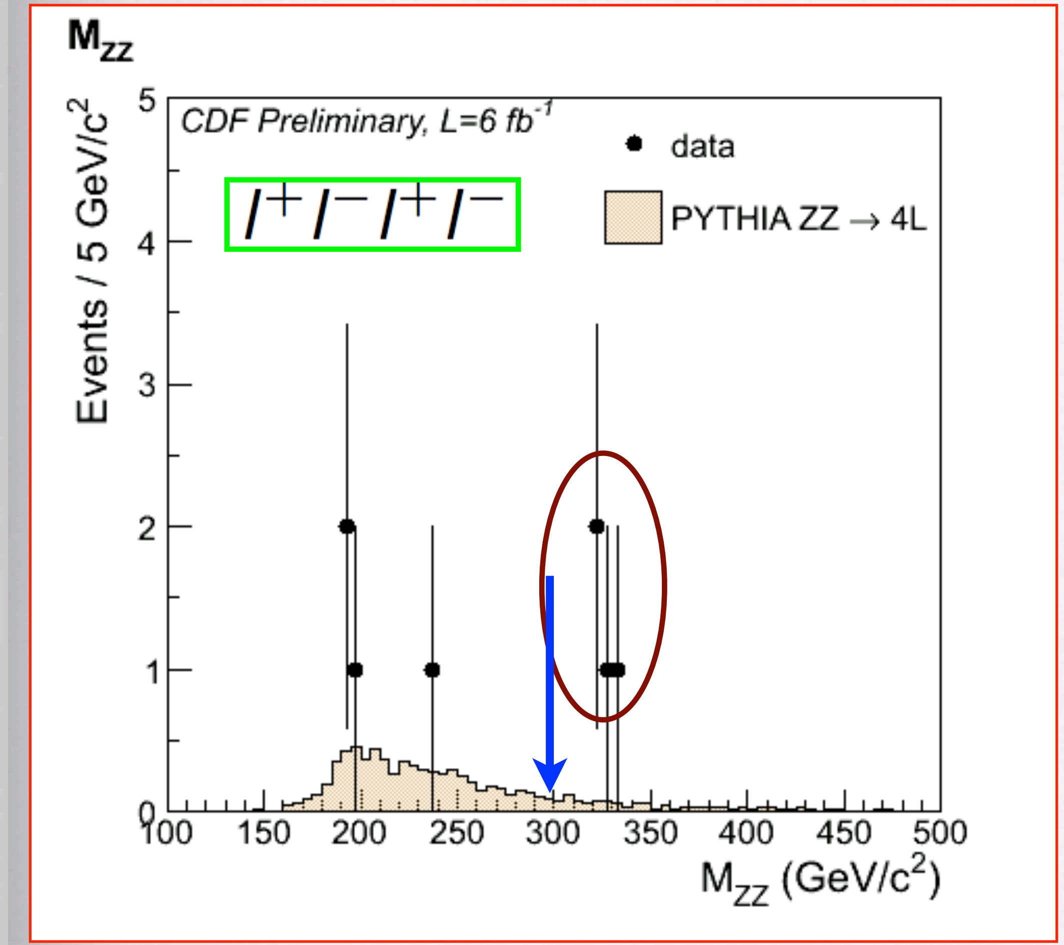
CDF public note 10479

D0: arXiv: 1008.2023 [hep-ex]

6 fb^{-1}

High Mass Resonance Decaying into ZZ

$ZZ \to l^+l^-l^+l^-$
$ZZ \to l^+l^-\nu\nu$
$ZZ \to l^+l^-jj$



$G^* \to ZZ?$

In the 4-lepton channel, 4 events observed with m_{ZZ}~**327 GeV** (eeee, eeμμ, 2μμμμ).

The total expected SM ZZ is 5.8, and less than 25% (1.5) of them have $m_{ZZ} > 300$ GeV.

The chance for 4 SM ZZ to cluster around 327 GeV is tiny (~10^{-4}).

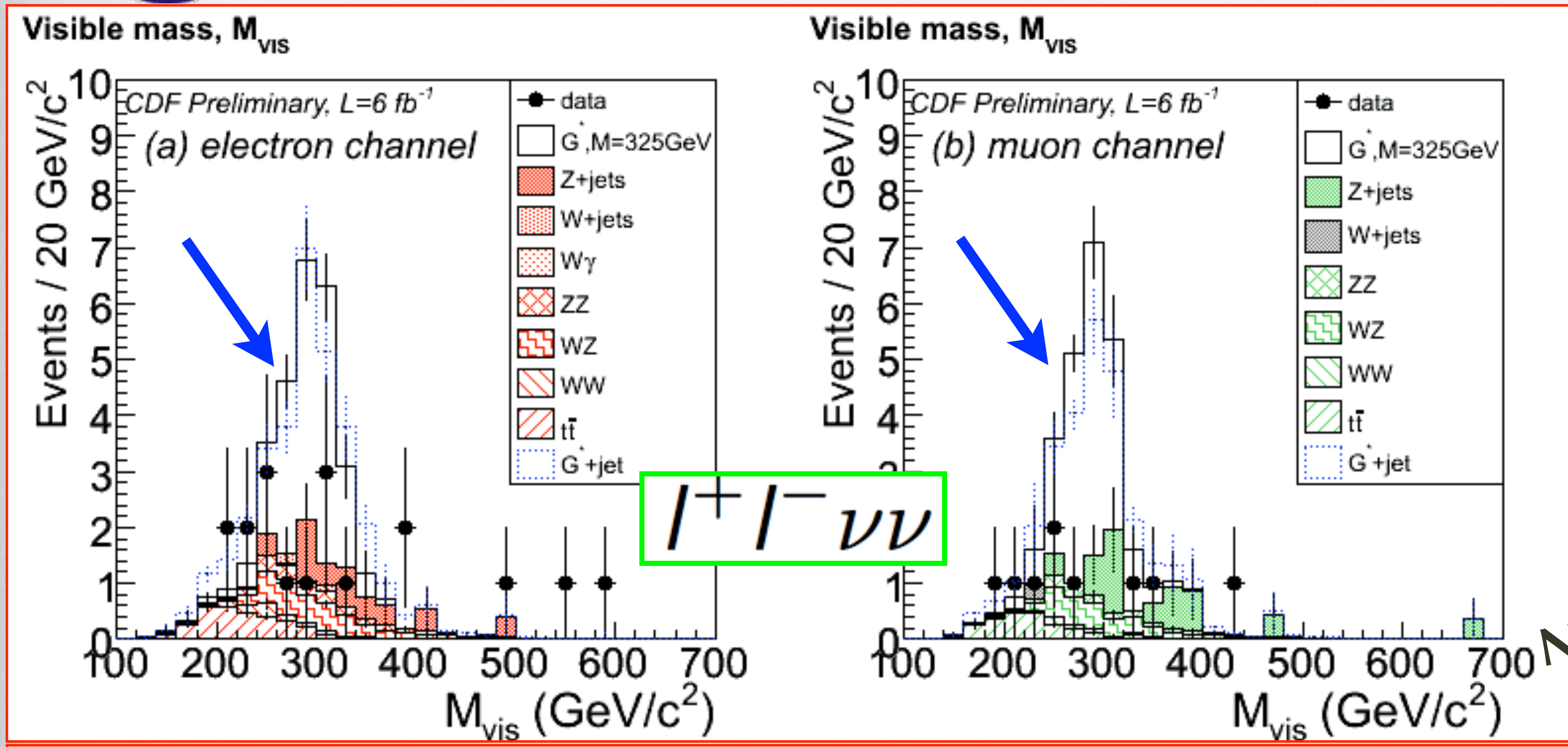
High Mass Resonance Decaying into ZZ

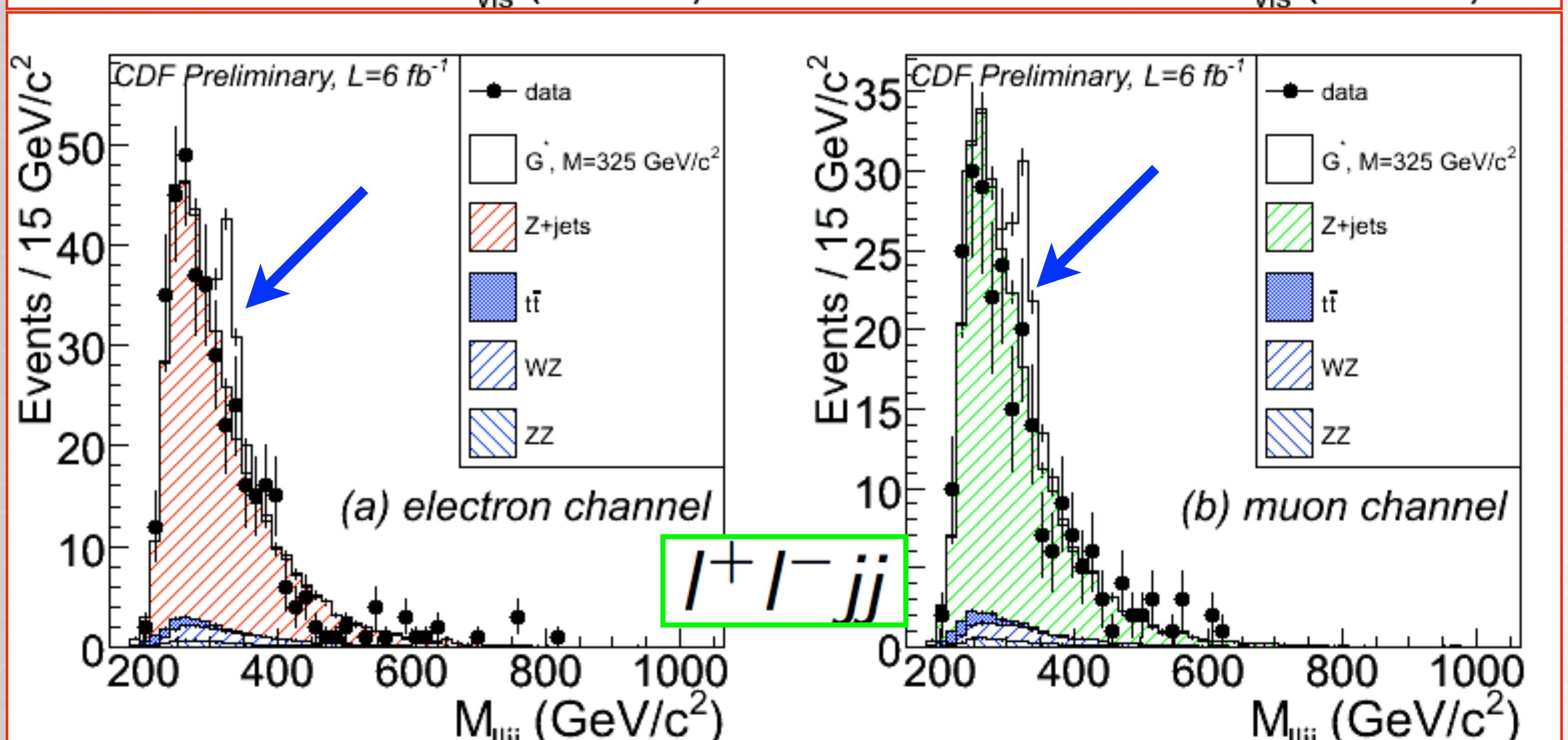
6 fb[-1]

$ZZ \to l^+l^-l^+l^-$

$ZZ \to l^+l^-\nu\nu$

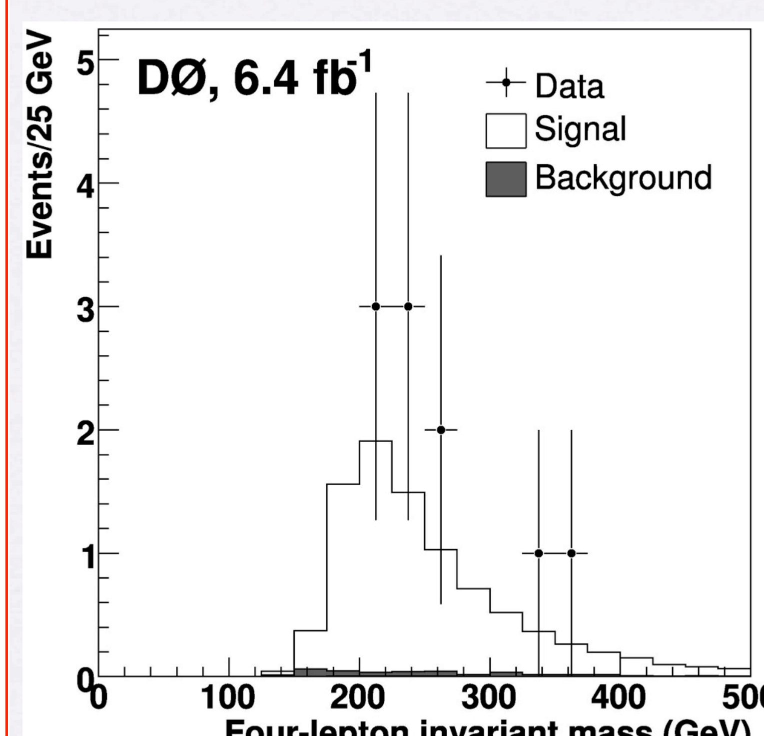
$ZZ \to l^+l^-jj$





$G^* \to ZZ?$

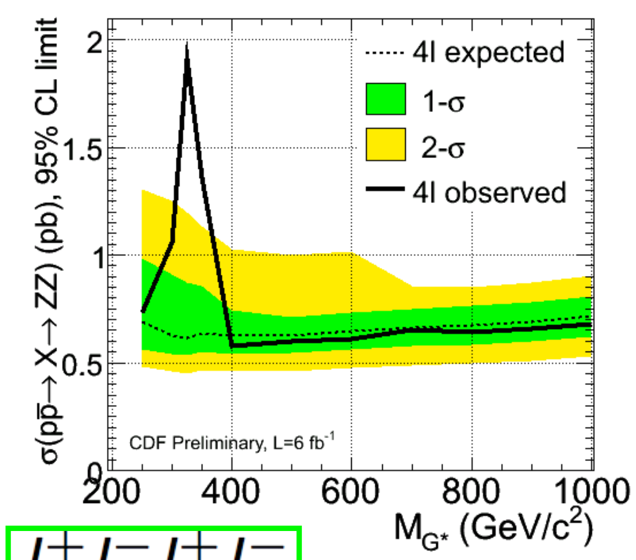
No excess around the expected high mass resonance



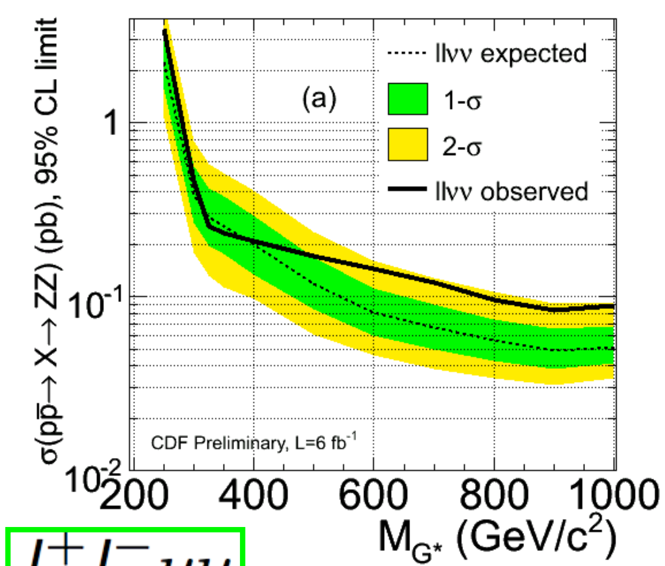
High Mass Resonance Decaying into ZZ

6 fb^{-1}

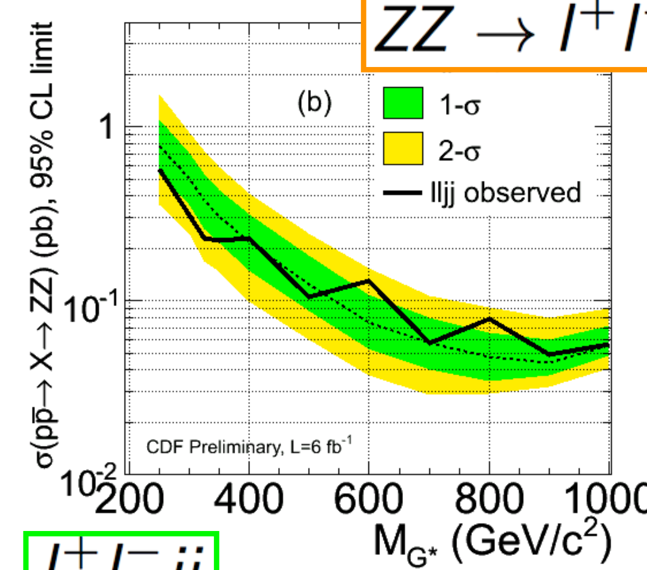
$ZZ \rightarrow l^+l^-l^+l^-$
$ZZ \rightarrow l^+l^-\nu\nu$
$ZZ \rightarrow l^+l^-jj$



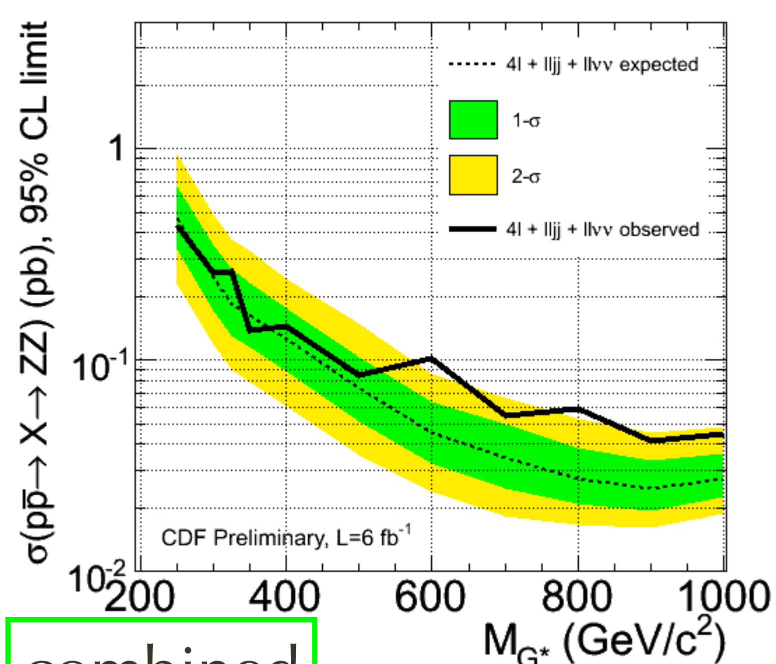
$l^+l^-l^+l^-$



$l^+l^-\nu\nu$



l^+l^-jj



combined

In 4-lepton channel, at m_{ZZ} = 325 GeV the expected upper limit is **0.7 pb**, and the observed is **1.9 pb**.

In llνν and lljj channel, the observed limits are consistent with the Standard Model expected.

<u>Story is not finished yet ...</u>

CDF public note 10603

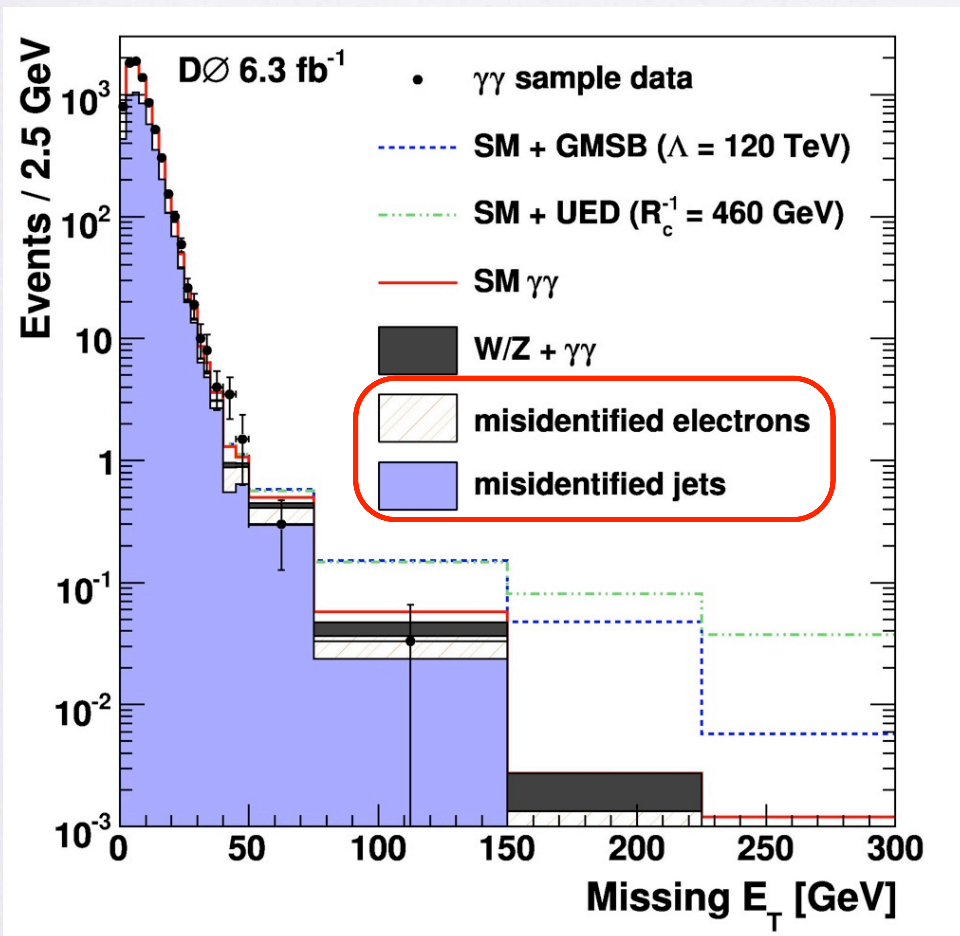
D0: PRD 84. 011103(R) (2011)

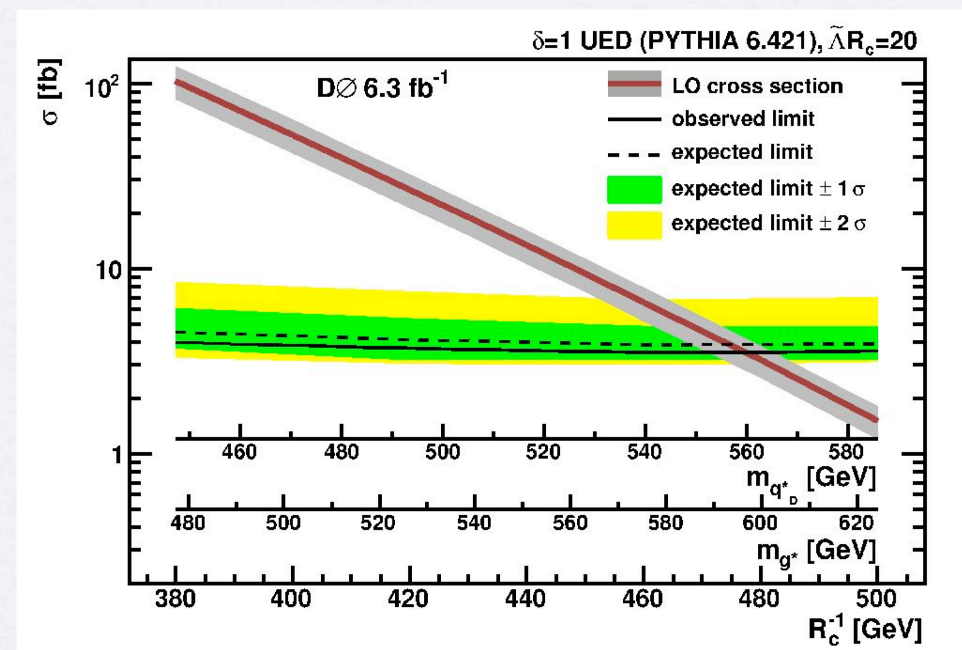
Search for γγ events with large MET

Lightest KK particle in UED model $\boxed{\gamma^* \rightarrow G\gamma}$

Update the previous analysis (1.1fb^{-1})

Improved photon ID utilizing neural network technique





- UED: compactification radius $R_c^{-1} < 477$ GeV

Phys. Rev. Lett. 105, 221802 (2010)

4 fb^{-1}

Search for 4th gen. neutrino in ZZ+MET

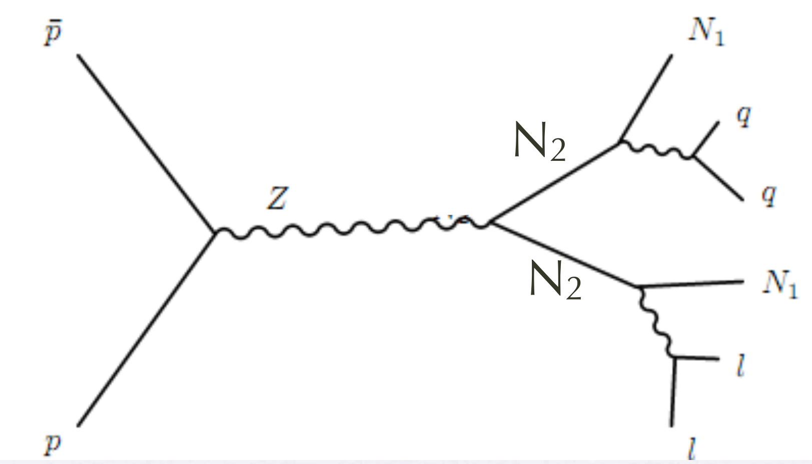
$$p\bar{p} \to Z/\gamma^* \to N_2 N_2 \to N_1 Z N_1 Z \to l^+ l^- q\bar{q} + \not{E}_T$$

Searches for 4th gen. quarks t′, b′ have been performed at Tevatron.

Not very much in searching for 4th gen. leptons.

Two eigenstates N1, N2 for the neutrino.

$N_2 \to N_1 Z$ dominates in most case.

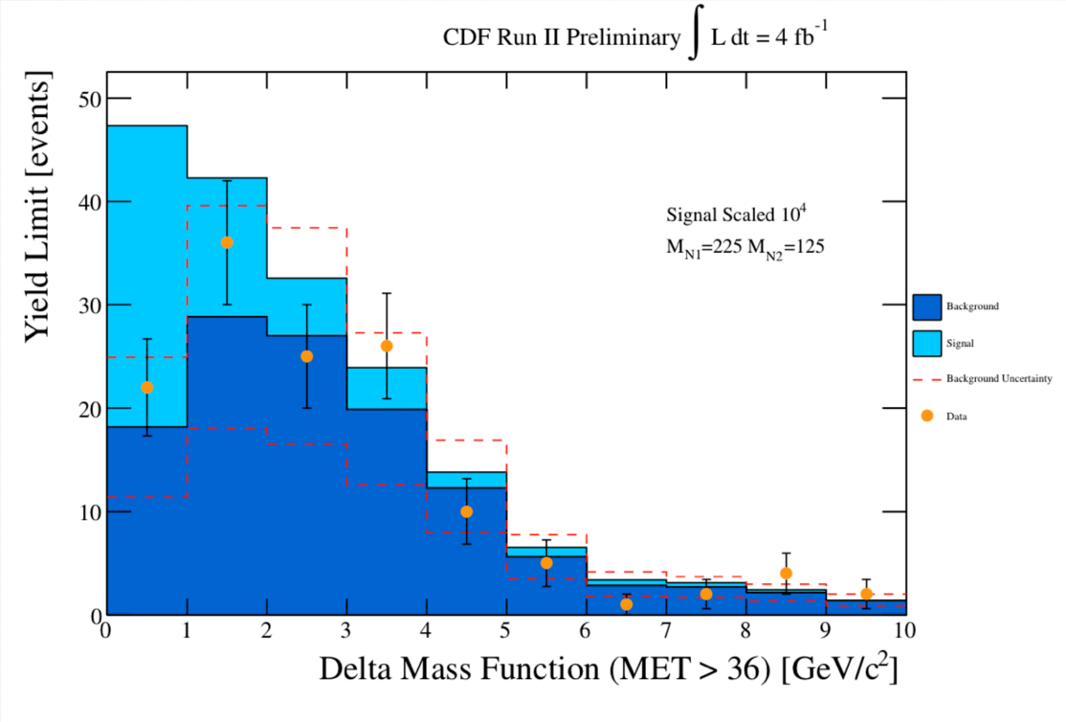


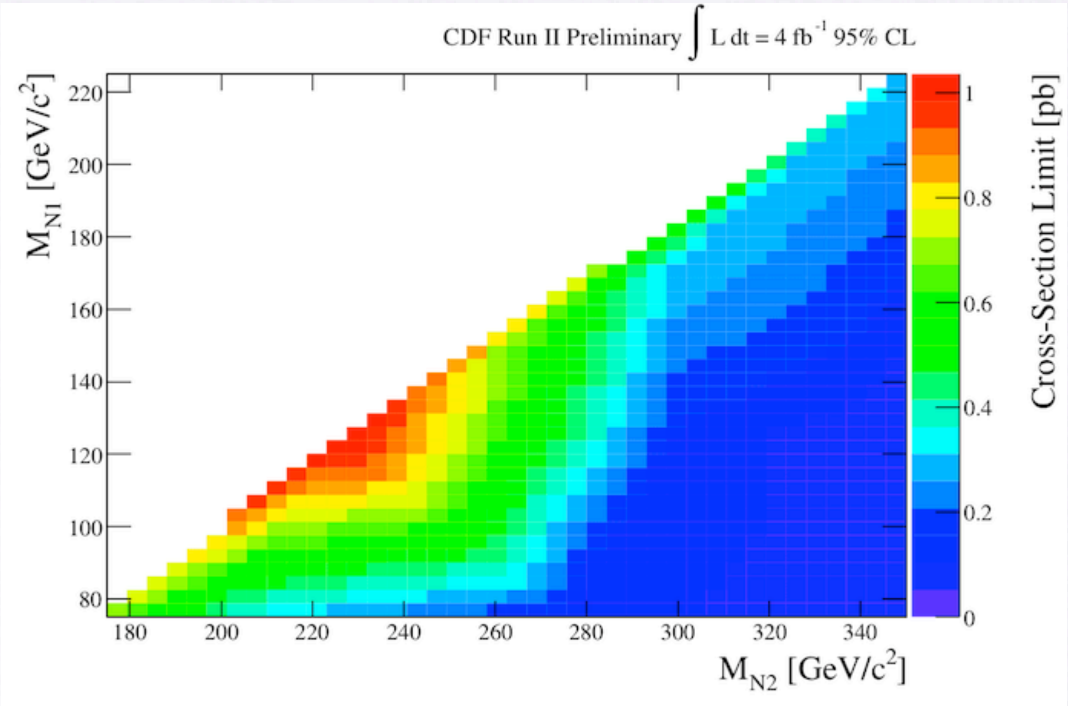
$$Delta\ Mass\ Function = \sqrt{(\frac{m_{ll} - 91.6}{10})^2 + (\frac{m_{jj} - 85.3}{15})^2}$$

Fitted Z mass

Fitted Z width

SM bkgs are either only having one Z or lacking of true MET



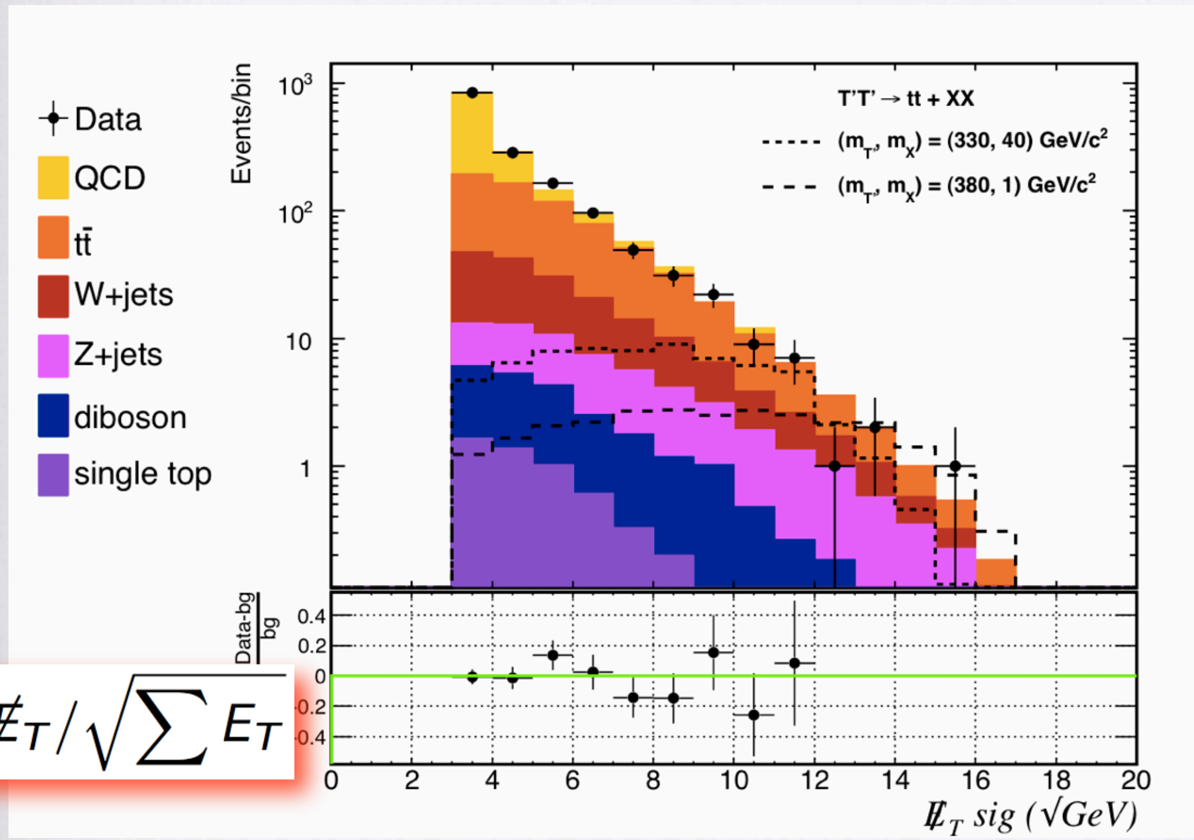


CDF public note 10539

Search for New Physics in tt+MET (all hadronic tops)

5.7 fb^{-1}

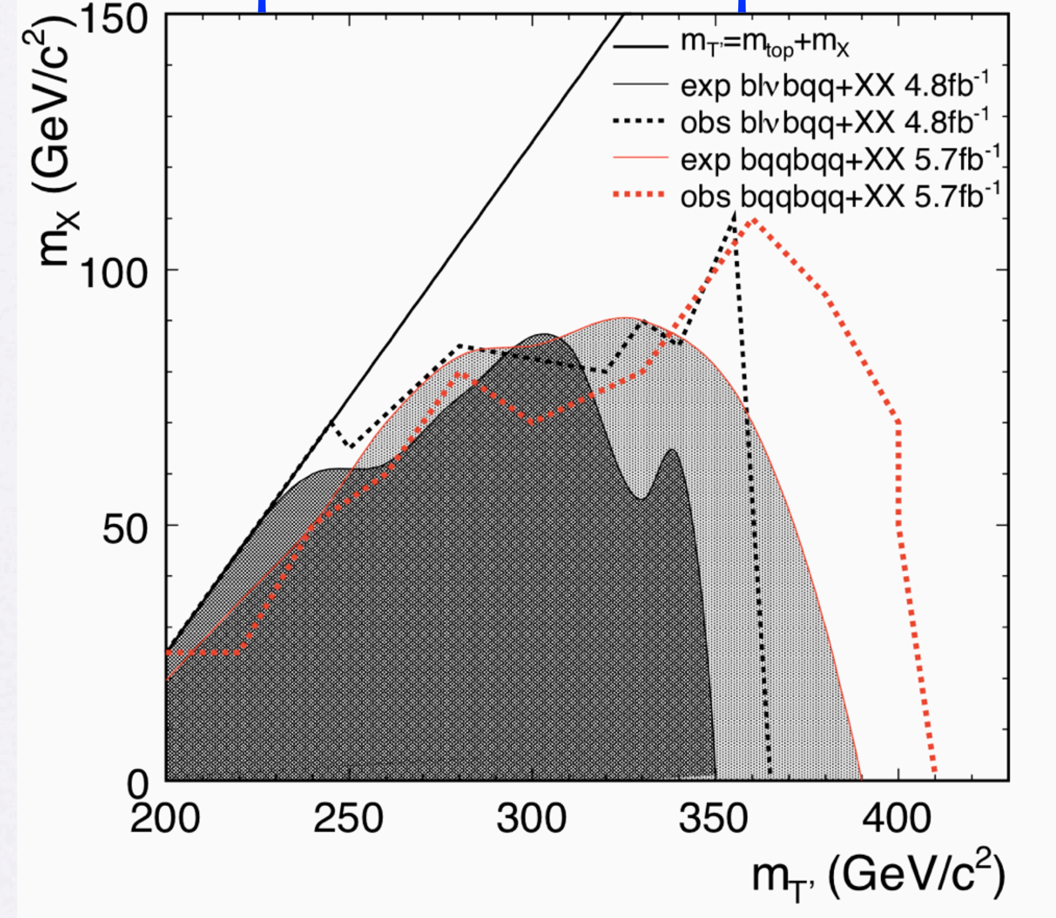
$$p\bar{p} \rightarrow t'\bar{t}' \rightarrow tX\bar{t}\bar{X} \rightarrow bqq'\bar{b}qq' + \not{E}_T$$



$$\not{E}_{T\,sig} = \not{E}_T / \sqrt{\sum E_T}$$

Major bkgs:
Top Pair: all hadronic decay, lack of true MET
QCD: fake MET, small METsig

In comparison to the one lepton search

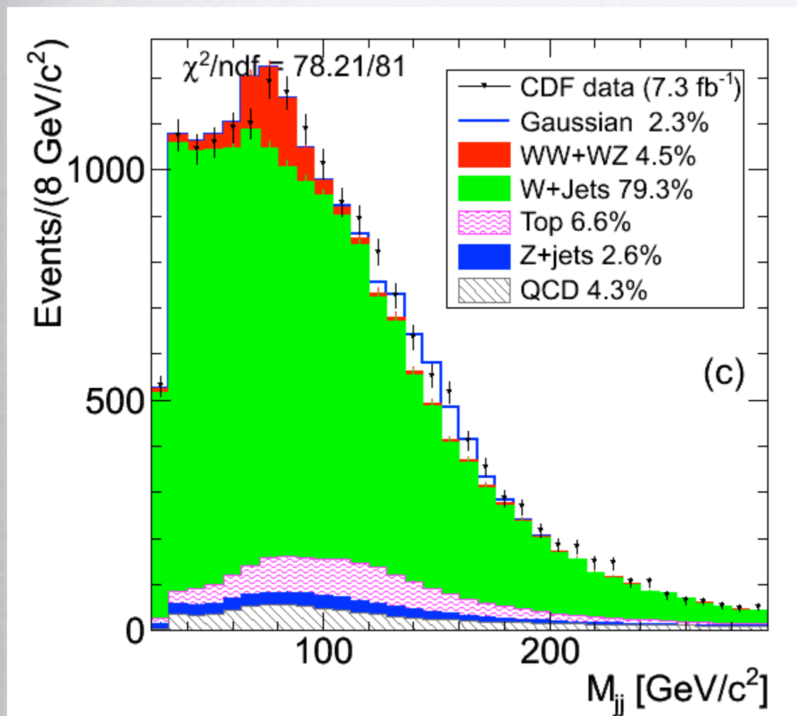


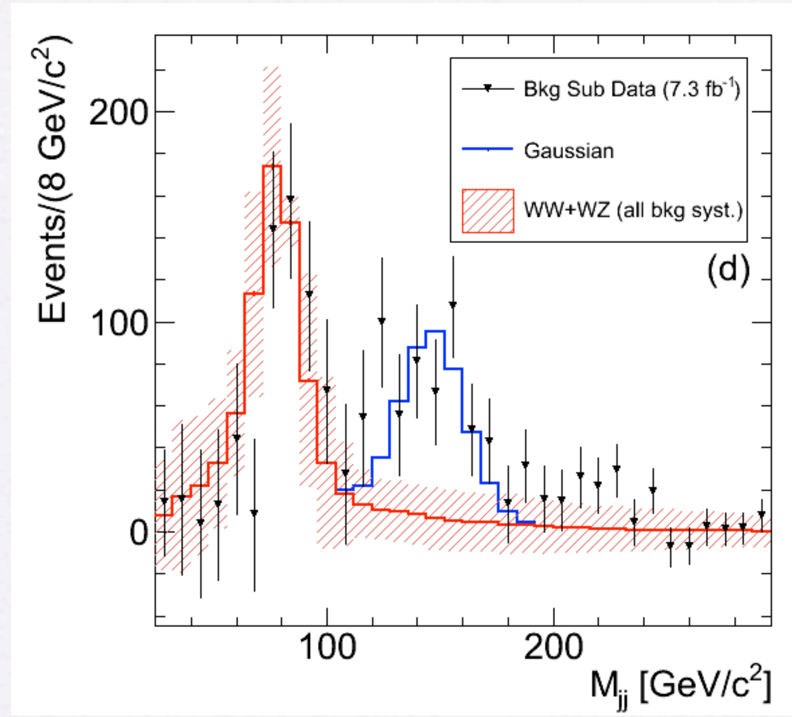
Exclude the fourth generation exotic quarks t′ up to 400 GeV for m_X < 70 GeV

arXiv:1107.3574

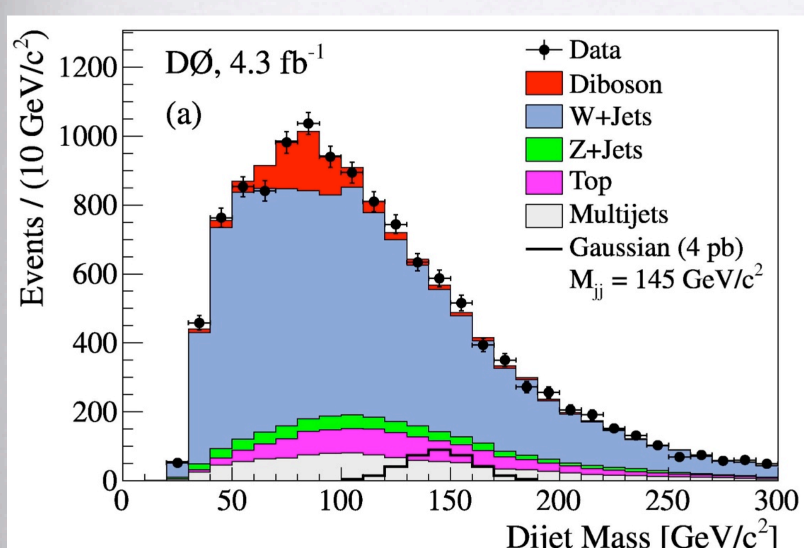
CDF lepton analysis: PRL 106, 191801 (2011)

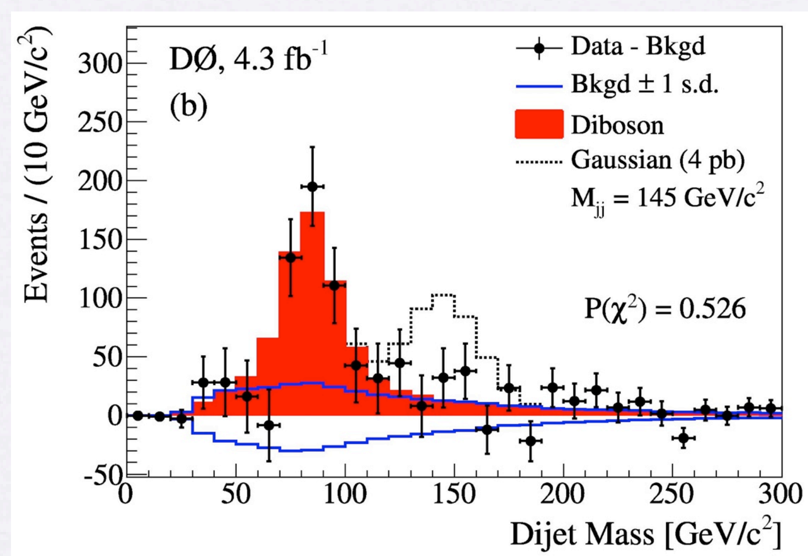
Dijet Resonance in W+jets





Updated to 7.3 fb^{-1}, the significance of the bump is 4.76





DØ's result doesn't favor such a resonance.

Task forces are commanded between CDF and DØ, and internally in these collaborations.

Conclusion

- Many new-physics signatures are explored both at CDF and DØ. Only very recent results are covered in this talk.
- Both experiments are expecting ~11 fb^{-1} data being finally acquired, which is twice as much the data explored so far. Stay tuned ...
- LHC is delivering many interesting exotic results, wish to hear more in SUSY 2011.
- For more exotic searches at Tevatron:
  - http://www-d0.fnal.gov/Run2Physics/np/
  - http://www-cdf.fnal.gov/physics/exotic/

A very emotional moment

- Many people have worked on/with CDF and DØ, and loved them.
- But the day just comes.
- Thanks, to the people, and to the machines!

Celebration will be around in the lab on Sept. 30

Still hard to have a broad perspective of physics